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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/622,645	07/21/2003	Koichi Ohto	8038-1011-2	4540

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EXAMINER	
KIELIN, ERIK J	
ART UNIT	**PAPER NUMBER**
2813	

DATE MAILED: 12/06/2004

Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	Application No.	Applicant(s)
	10/622,645	OHTO, KOICHI
	Examiner	**Art Unit**
	Erik Kielin	2813

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *21 July 2003*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-7* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-7* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *21 July 2003* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☒ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☒ Certified copies of the priority documents have been received in Application No. 09/727,675.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☒ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date *7/21/2003*.

4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

5) ☐ Notice of Informal Patent Application (PTO-152)

6) ☐ Other: _____.

DETAILED ACTION

Priority

1. Acknowledgment is made of applicant's claim for foreign priority under 35 U.S.C. 119(a)-(d). The certified copy has been filed in parent Application No. 09/727,675, filed on 4 December 2000.

Claim Rejections - 35 USC § 112

2. The following is a quotation of the first paragraph of 35 U.S.C. 112:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same and shall set forth the best mode contemplated by the inventor of carrying out his invention.

3. Claims 1-7 are rejected under 35 U.S.C. 112, first paragraph, as based on a disclosure which is not enabling. Introducing a source of nitrogen along with the claimed SiH_4, critical or essential to the practice of the invention, but not included in the claim(s) is not enabled by the disclosure. See *In re Mayhew*, 527 F.2d 1229, 188 USPQ 356 (CCPA 1976). The last step in claim 1 requires the formation of SiN (silicon nitride) cap on the copper interconnect. SiN cannot be formed in the absence of a source of nitrogen. Accordingly, introducing a source of nitrogen along with the claimed SiH_4 is critical to the practice of the invention. The remaining claims are rejected for depending from the above rejected claim 1.

4. Claims 1-7 are rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the written description requirement. The claim(s) contains subject matter which was not described in the specification in such a way as to reasonably convey to one skilled in the relevant

art that the inventor(s), at the time the application was filed, had possession of the claimed invention.

The original specification fails to provide support for heating the susceptor to 400 °C "after the first time period" the first time period being that time during which the copper oxide is exposed to the RF plasma, as presently claimed in claim 1. Instead the instant specification states,

> "The surface oxide layer of the copper interconnect formed on the silicon substrate was reduced and removed by applying 100 W of the RF power having 13.56 MHz for 10 seconds from a RF plasma source 16 in a pretreatment (Fig.2C). Then, the lift pins 14 were descended to place the silicon wafer on a susceptor 12 which **had been heated** to 400 °C by a heater 13 (Fig.2D)." (Emphasis added.)

Accordingly the original specification fails to provide support for the claimed connection between "the first time period" as limiting of the time before which the susceptor heating begins.

The remaining claims are rejected for depending from the above rejected claim 1.

Claim Rejections - 35 USC § 103

5. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

6. Claims 1-7 are rejected under 35 U.S.C. 103(a) as being unpatentable over US 6,255,217 B1 (**Agnello** et al.) in view of US 6,355,571 B1 (**Huang** et al.) and Applicant's admitted prior art (**APA**).

Regarding claim 1, **Agnello** discloses a method of capping a copper damascene interconnect in a semiconductor device comprising,

placing the semiconductor device (Fig.) in a "conventional plasma deposition apparatus" (col. 4, lines 21-23);

introducing a gas containing hydrogen, specifically ammonia (NH_3) or ammonia plus nitrogen (N_2), into the deposition chamber to achieve a first pressure of 5 Torr therein (col. 4, lines 13-20; col. 5, Table 1);

introducing RF power of 50 to 10,000 watts, with an example of 300 watts, into the deposition chamber while the ammonia or ammonia and nitrogen is present and while not heating the semiconductor device to exposure the copper surface to the reducing plasma at 20 °C, for example, for a period of time of 1 to 3600 seconds, preferably 5 to 30 seconds (col. 4, lines 21-37 -- especially lines 24-26) after which time it would be expected that the RF power is stopped in order to have the indicated exposure time period;

after the first time period, *in situ* forming a silicon nitride capping layer **24** (called "barrier layer" in **Agnello**) on the copper interconnect **20** using conventional plasma deposition techniques (col. 3, lines 48-67) which **Agnello** teaches are conventionally 200 °C to 500 °C (col. 1, lines 43-50).

Agnello does not specifically indicate that the reducing plasma exposure removes oxide, but it inherently must remove any oxide because the same method as used by Applicant has been used. Furthermore, because **Agnello** uses conventional methods to form the damascene copper interconnect (col. 3, lines 32-37), which would involve chemical-mechanical planarization, the copper surface would necessarily have a native oxide film. Furthermore, **Huang** specifically

teaches that such ammonia plasma exposure removes surface copper oxides. (See **Huang**, col. 1, lines 50-58; col. 2, lines 46-48.) Accordingly, it is held absent evidence to the contrary that the **Agnello** copper interconnect has surface oxide which is removed, as per the evidence given by at least **Huang**. (See MPEP 2112.)

Agnello does not teach that silane is used to form the silicon nitride capping layer on the copper interconnect.

Huang teaches an almost identical method for forming a capping layer **108** on a copper interconnect to that in **Agnello**, including the ammonia plasma treatment of the copper interconnect **106**, followed by *in situ* deposition of silicon nitride using plasma-enhanced CVD, wherein silane (SiH_4) and ammonia are used to deposit the silicon nitride capping layer. Further deposition parameters for the silicon nitride film include a temperature specifically of 400 °C, as further limited by instant claim 14. (See col. 6, lines 6-20 -- especially line 11.)

It would have been obvious for one of ordinary skill in the art, at the time of the invention to form the silicon nitride layer, as taught by **Huang,** in the method of **Agnello,** including the use of at least the silane (SiH_4) and the deposition temperature, because **Agnello** has given no specific materials or temperatures for deposition of the silicon nitride layer, indicating instead that conventional methods are used, such that one of ordinary skill would be especially motivated to discover the best deposition method for a similar process of producing a silicon nitride capping layer after an ammonia plasma treatment, such as the one disclosed in **Huang**. Also, **Agnello** teaches that, because copper is used, temperatures of less than 450 °C should be used (col. 1, lines 43-45). Because **Huang** teaches that 400 °C is an exemplary good temperature for depositing silicon nitride from silane on copper damascene interconnect after ammonia

plasma treatment, just as **Agnello** has used from silane, one of ordinary skill would be motivated to following this exemplary method.

Then the only difference is that **Agnello** and **Huang** do not teach (1) that the semiconductor device is spaced from the susceptor when placed into the chamber, or (2) that heating the semiconductor device to 400 °C is accomplished by lowering the semiconductor device onto the heated susceptor.

APA teaches that it is known in the art (1) to load a semiconductor substrate is loaded into a plasma treatment/deposition chamber initially on the lift pins away from the susceptor (APA prior art Fig. 1A; p. 3, lines 6-8), and (2) to control the temperature of a semiconductor substrate by raising and lowering the substrate relative to a heated susceptor (APA prior art Figs. 1B-1D; p. 3, lines 8-10).

It would have been obvious for one of ordinary skill in the art, at the time of the invention to initially place the semiconductor device of **Agnello** on lift-pins and to perform the plasma treatment in ammonia or ammonia plus nitrogen, above and spaced away from the susceptor because **APA** teaches that this is how a semiconductor substrate is loaded into a conventional deposition chamber and because **Agnello** teaches that the ammonia plasma treatment can be carried out at 20 °C. Because **APA** teaches that the temperature is controlled by positioning the substrate relative to the heating susceptor, one of ordinary skill would recognize that elevation would prevent heating, as desired in **Agnello**.

It would be obvious to heat the semiconductor device of **Agnello** by lowering the semiconductor device to the susceptor in order to heat the semiconductor device because **APA** teaches that heating is conventionally accomplished by lowering the semiconductor device to the

susceptor, and because both **Agnello** and **Huang** teach that the silicon nitride layer should be deposited at elevated temperatures (200 °C to 500 °C in Agnello and 400 °C in Huang).

Further in this regard, there exists no evidence of record that the manner by which the semiconductor device is loaded into and heated by the apparatus is critical to the invention, so long as the device is, in fact, loaded and heated for the forming of the silicon nitride. Rather, all that has been indicated to be critical is that the ammonia plasma reduction of the copper oxide be carried out at a temperature less than 300 °C (instant specification, problem at p. 4, lines 5-14 and solution at p. 5, 4-12). Accordingly, the method by which the semiconductor device is loaded and heated is merely obvious conventional methodology, as taught by **APA**.

Regarding claim 2, as noted above, **Agnello** indicates that both NH_3 and N_2 may be used as the gases for the reductive plasma exposure of the copper interconnect.

Regarding claim 3, **Agnello** does not specifically teach 10 seconds but, as noted above, teaches preferred exposure times of 5 to 30 seconds. **Huang** specifically teaches a 10 second plasma exposure time to the ammonia plasma to remove surface oxide. (See **Huang**, col. 2, line 61, to col. 3, line 3.) It would have been obvious for one of ordinary skill in the art, at the time of the invention to use the 10-second exposure time of **Huang** in the method of **Agnello**, for the combined reasons indicated in each.

(CHECK) Regarding claims 4 and 5, **Agnello** does not specifically teach 100 watts of RF power at 13-14 MHz, but does teach powers of 50 to 10,000 watts may be used with preferred powers of about 150 to 400 watts (col. 4, lines 33-49). **Huang** also teaches RF power in the range of 50-500 watts with a 150-watt preference for the plasma treatment. In this regard, it has been held that the selection of optimum conditions within prior art conditions is *prima*

facie obvious in the absence of unexpected results. In the instant case, the removal of the copper oxide layer and the consequent improved adhesion of the silicon nitride cap layer are the stated results of both the **Agnello** and **Huang** methods, just as indicated in the instant specification. Accordingly there is presently no evidence of unexpected results for 100 watts.

It would have been obvious to one of ordinary skill at the time of the invention to use any power, which would achieve the results of removing the oxide and improving the adhesion of the SiN capping layer, within the prior art disclosed conditions of **Agnello** and **Huang**. (See MPEP 2144.05.)

Agnello does not recite the very well known, industry standard, RF power of 13-14 MHz, but **Huang** teaches that the RF power is 13.56 MHz (**Huang**, col. 5, line10).

It would have been entirely obvious for one of ordinary skill in the art, at the time of the invention to use recognized industry standard radio frequencies to form the plasma in **Agnello,** because **Agnello** indicates that conventional plasma deposition apparatus is used to expose the copper interconnect (**Agnello**, col. 4, lines 21-24), and because **Huang** teaches the conventional RF of 13.56 MHz is used.

Regarding claim 6, as noted above, **Agnello** teaches 5 Torr as the pressure for ammonia plasma treatment.

Regarding claim 7, **Agnello** does not indicate that the semiconductor device is elevated on lift pins away from the susceptor for removal, but **APA** teaches that this is conventional in the art (instant specification p. 3, lines 15-17; prior art Fig. 1E).

It would have been obvious for one of ordinary skill in the art, at the time of the invention to lift the semiconductor device is elevated on lift pins away from the susceptor for removal

because **Agnello** teaches that conventional plasma deposition apparatus and conventional SiN deposition conditions are used and **APA** teaches that such lifting on lift pins for removal is conventional. Moreover, there exists no evidence of record that the method of removing the semiconductor device has any impact whatsoever on the resulting semiconductor device. In short, it is not critical to the practice of the invention.

Conclusion

7. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

The machine language translations of the references cited in the IDS filed 21 July 2004 are included as well as the communication from the Japanese Patent Office citing a portion of these references, as well as an English translation, that were provided by Applicant in the parent application 10/212,234, now abandoned.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Erik Kielin whose telephone number is 571-272-1693. The examiner can normally be reached on 9:00 - 19:30.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Carl Whitehead, Jr. can be reached on 571-272-1702. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Erik Kielin
Primary Examiner
December 5, 2004